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ORGANIC-WALLED MICROPHYTOPLANKTON ABUNDANCE AND STRATIGRAPHIC DISTRIBUTION FROM THE MIDDLE DEVONIAN COLUMBUS AND DELAWARE LIMESTONES OF THE HAMILTON QUARRY, MARION COUNTY, OHIO[1]

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ABSTRACT. Forty-three species representing 25 genera of organic-walled microphytoplankton were recovered from a 28.04–m thick section of the Middle Devonian Columbus and Delaware Limestones of central Ohio, USA. This assemblage compares closely with other Middle Devonian microphytoplankton assemblages from North America, indicating their potential use as biostratigraphic guides. Their stratigraphic distribution is probably related in part, to the Columbus-Delaware carbonate lithofacies. The organic-walled microfossils are neither abundant nor well-preserved in the porous dolomite near the bottom of the Columbus Limestone. This poor preservation is probably a consequence of dolomitization, while their paucity may reflect an original shallow-water environment of restricted circulation. Such an environment may not have been conducive to plankton growth. The microphytoplankton assemblage increases in numerical abundance and diversity in the overlying non-dolomitized carbonates, particularly the finer-grained limestones.

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INTRODUCTION

The carbonates of the Columbus and superjacent Delaware Limestone were deposited during the Early Devonian (Emsian) with deposition continuing into the Middle Devonian (Givetian). Sediment accumulation occurred east of the Wabash Platform, a dominant paleogeographic feature of Illinois, Indiana and Ohio (Droste et al. 1975, Wright 1976, 1978, 1980). This platform, which separated the Illinois Basin from the Michigan and Appalachian Basins, was emergent in Eifelian time. Consequently, carbonate deposition in central Ohio was in proximity to carbonate flats and tidal lagoons to the west in Indiana. Planktonic algae were prolific in these sunlit waters.

Organic-walled microphytoplankton are the presumed cysts of marine planktonic algae. They can be divided into the Chlorophyta (green algae) and Acritarcha (unknown affinity). They tend to be abundant, generally well preserved, and geographically widespread in distribution. As their stratigraphic ranges and areal distribution become better known, they are proving to be biostratigraphically useful in correlating Paleozoic rock units. Thus the description of the organic-walled microphytoplankton from previously studied outcrop exposures such as the Columbus and Delaware Limestones (Stauffer 1909, Conkin and Conkin 1975) is important in establishing their stratigraphic occurrence.

METHODS AND MATERIALS

For this study, 18 samples were chosen representing the various carbonate lithofacies and depositional environments of the Columbus and Delaware Limestones (fig. 1). Approximately 50 g of sample were processed using standard palynological techniques, which consisted of treatment in hydrochloric, hydrofluoric, and nitric acids; removal of the undissolved "heavy" minerals by panning; and screening through either a 38 μm of 20 μm screen. From the remaining residue, slides were then prepared. For relative abundance data, 2–5 slides were

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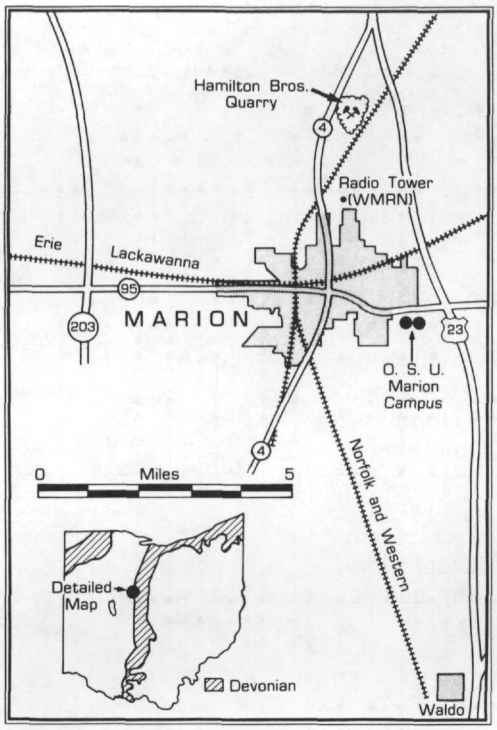

FIGURE 1. Map showing the location of the Hamilton Brothers Quarry, Marion, Ohio.

examined, and counts were calculated on the basis of 3 slides/sample to maintain uniformity throughout the section. We counted all specimens on each slide. The number of slides varied (2–5) because the same amount of material was used per sample to maintain uniformity between samples. In some cases, only enough residue was left to make 2 slides. As is evident from fig. 2, most species exhibit low abundance throughout the section.

STRATIGRAPHY

At the Hamilton Quarry in Marion County, Ohio (figs. 1,2) a section of the Middle Devonian Columbus and Delaware Limestones, 28.04 m thick, was measured and sampled for organic-walled microfossils. The lower 6.10 m of the section is primarily porous recrystallized dolomite stained with hydrocarbons and containing chert lenses. The dolomite contains fossil molds of corals and is totally devoid of chitinozoans (Wright 1976), but it does contain an assemblage of 20 species of poorly preserved organic-walled microphytoplankton. The dolomitized carbonates may have been deposited in a shallow-water environment with restricted circulation just east of the Wabash Platform.

The overlying coral-stromatoporoid zone may represent a period of normal open marine conditions with good water circulation. Immediately above the coral-stromatoporoid horizon, the organic-walled microfossils increase in abundance and diversity and are better preserved. The fossiliferous limestone in this part of the section, up to the chert-bearing limestone at sample 28, represents a depositional site at or near wave base (Chapel 1975) with good water circulation.

The 3.05 m of cherty fine-grained limestone between samples 28-34 are of interest because this interval does not contain many megafossils, has a high concentration of chitinozoans (Wright 1976), and contains 30 species of organic-walled microphytoplankton. The abundance in these samples is somewhat higher than for any other interval. Chapel (1975) considered this interval a regressive phase representing a semi-restricted deposit above wavebase, perhaps even somewhat lagoonal.

The fossiliferous limestone of the uppermost Columbus Limestone, and the 3.66 m of overlying Delaware Limestone, reflects a deepening of the water that continued into Middle Devonian time (Wright 1978). This interval contains only 17 species of organic-walled microphytoplankton from 3 samples.

Generally, then, the occurrence and the abundance of the organic-walled microphytoplankton assemblage throughout the section appear to be a reflection of the lithofacies and depositional environment. The greatest diversity and abundance of microphytoplankton occur in the calcareous mudstone (except for the Delaware Limestone). Chitinozoa are also abundant in this lithofacies (Wright 1976). However, while no chitinozoans were found in the lower dolomite facies, 20 species of organic-walled microphytoplankton were recovered. The state of preservation of the

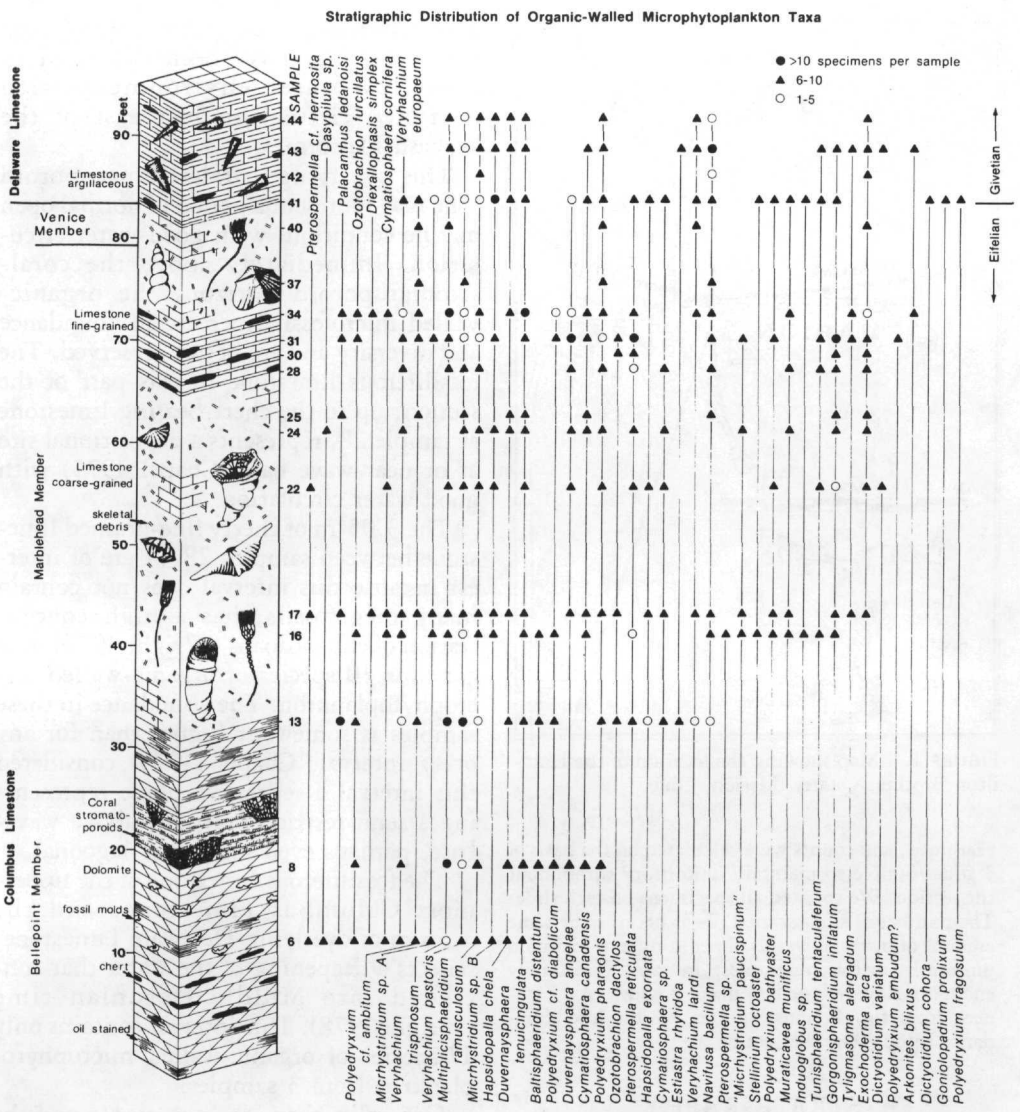

FIGURE 2. Stratigraphic section of the Columbus and Delaware Limestones showing the carbonate lithofacies and distribution and abundance of organic-walled microphytoplankton.

assemblage can generally be regarded as a reflection of microphytoplankton entombment in a carbonate matrix and the subsequent alteration due to diagenesis of those carbonates.

DISCUSSION

Forty-three species of organic-walled microphytoplankton were recovered from the Columbus and Delaware Limestones. All except 2 species have been previously reported in the literature. These 2 species (*Cymatiosphaera* sp. and *Induoglobus* sp.) are probably new, but only a few specimens of each were found. We felt there was an insufficient number of specimens to justify establishing new species. The range of the genus *Induoglobus* is now extended into the Middle Devonian, having been found previously only in the Lower Devonian Gedin-

nian of Oklahoma (*Induoglobus latipenniscus* Loeblich and Wicander 1976).

The organic-walled microphytoplankton assemblage shows a high degree of similarity to the younger Middle Devonian Givetian-aged Silica Formation of Ohio (Wicander and Wood 1981). Thirty of the 43 species from the Columbus and Delaware Limestones are also found in the Silica Formation. This assemblage is also similar to that of the Middle Devonian Onondaga Limestone of Ontario, Canada (Deunff 1954a, 1955, 1957, 1961, 1966a, 1971), and contains recurring species with the Middle Devonian Hamilton Formation of Ontario, Canada (Legault 1973) such as *Arkonites bilixus* Legault 1973, and *Estiastra rhytidoa* Wicander and Wood 1981, among others.

The Columbus-Delaware organic-walled microphytoplankton assemblage also has some species in common with the Late Siegenian to Givetian-aged Jaab Lake No. 1 Well in the Moose River Basin, northern Ontario, described by Playford (1977). Of particular interest is the occurrence of *Goniolopadion prolixum* Playford 1977. This species has been reported by Playford (1977) only from the Williams Island Formation (Givetian) in the Jaab Lake No. 1 Well, northern Ontario. In that formation, it is recovered from a limestone unit (as it is here) and not from a calcareous shale interval within either the Williams Island Formation or the Silica Formation. Perhaps this species is lithofacies restricted. Obviously more work needs to be done in this regard, but species/lithofacies relationships is an area of promising research as more is learned about the temporal and spatial distribution of organic-walled microphytoplankton.

As noted by Wicander and Wood (1981) only a few North American Middle Devonian organic-walled microphytoplankton assemblages have been described, and of these, most only list a few species. Hence, the comparisons to other Middle Devonian formations that Wright (1976) was able to make for the chitinozoans, is not yet possible with any real precision for the organic-walled microphytoplankton.

It is precisely because so few Middle Devonian organic-walled microphytoplankton assemblages have been reported that we are describing this assemblage from the Columbus and Delaware Limestones. We hope that greater biostratigraphic refinement will ensue from such studies.

SYSTEMATIC PALEONTOLOGY

We list here only the valid name and North American geologic range (Early, Middle, Late) for the species recovered from the Columbus and Delaware Limestones at the Hamilton Quarry, Marion County, Ohio. For a complete synonymy with world-wide geologic range and geographic distribution, the reader is referred to Wicander and Wood (1981) and Wicander (in press).

All figured specimens are deposited in the Museum of Paleontology, Department of Geology, Central Michigan University, Mount Pleasant, MI 48859. Numbers given as CMUMP#5160, #43 > 20 μm 1,116.7; 16.1 refer to Central Michigan University Museum of Paleontology depository number (CMUMP#5160), sample number (#43), size fraction and slide number of that size fraction (>20 μm), and microscope coordinates (116.7; 16.1) on Central Michigan University Department of Geology Olympus Microscope #64387.

DIVISION CHLOROPHYTA CLASS PRASINOPHYCEAE

Order Halosphaerales Family Pterospermataceae

Genus *Cymatiosphaera* O. Wetzel ex Deflandre 1954

Cymatiosphaera canadensis Deunff 1961 fig. 3, (1) N. Amer. Geol. Range: L. Siegenian–L. Givetian.

Cymatiosphaera cornifera Deunff 1955 fig. 3, (2) N. Amer. Geol. Range: L. Siegenian–L. Famennian.

Cymatiosphaera sp. fig. 3, (3) DESCRIPTION: Vesicle circular in outline, 20 μm in diameter; vesicle surface divided into 12, laevigate, polygonal fields, 6 per hemisphere, 12–14 μm in diameter; fields separated by membranous, laevigate, round-topped ridges; 6 μm high; overall diameter 34-36 μm; no method of excystment observed. REMARKS: Only a few specimens of this distinctive species were recovered and it was decided not to name species on such a limited number of specimens.

Genus *Dictyotidium* Eisenack emend. Staplin 1961

Dictyotidium cohora Wicander and Wood 1981 fig. 3, (4) N. Amer. Geol. Range: E.–L. Givetian.

Dictyotidium cf. *variatum* Playford 1977 fig. 3, (5) N. Amer. Geol. Range: L. Siegenian–L. Givetian.

Genus *Duvernaysphaera* Staplin 1961

Duvernayspahera angelae Deunff 1964 fig. 3, (6) N. Amer. Geol. Range: E.–L. Givetian.

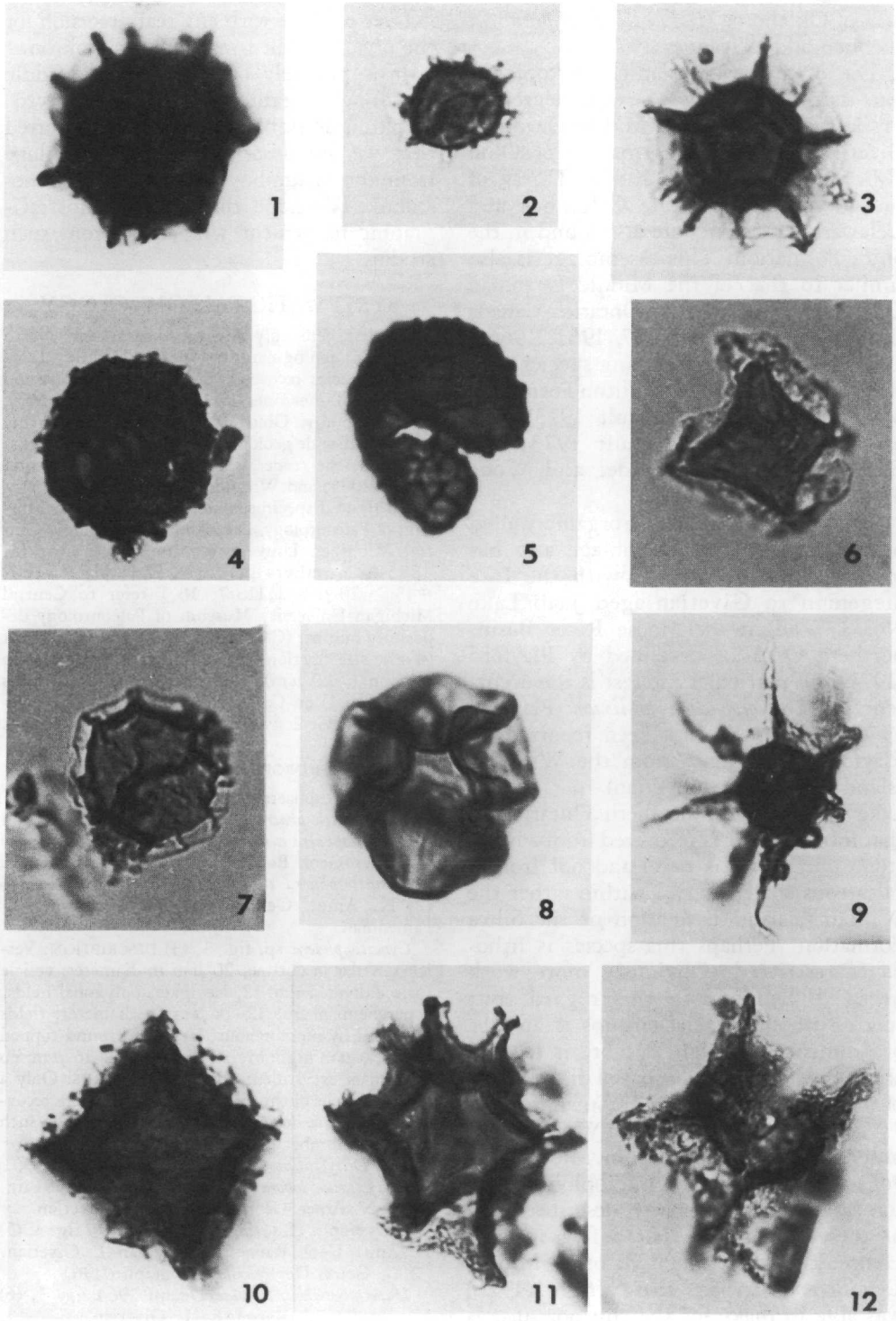

FIGURE 3

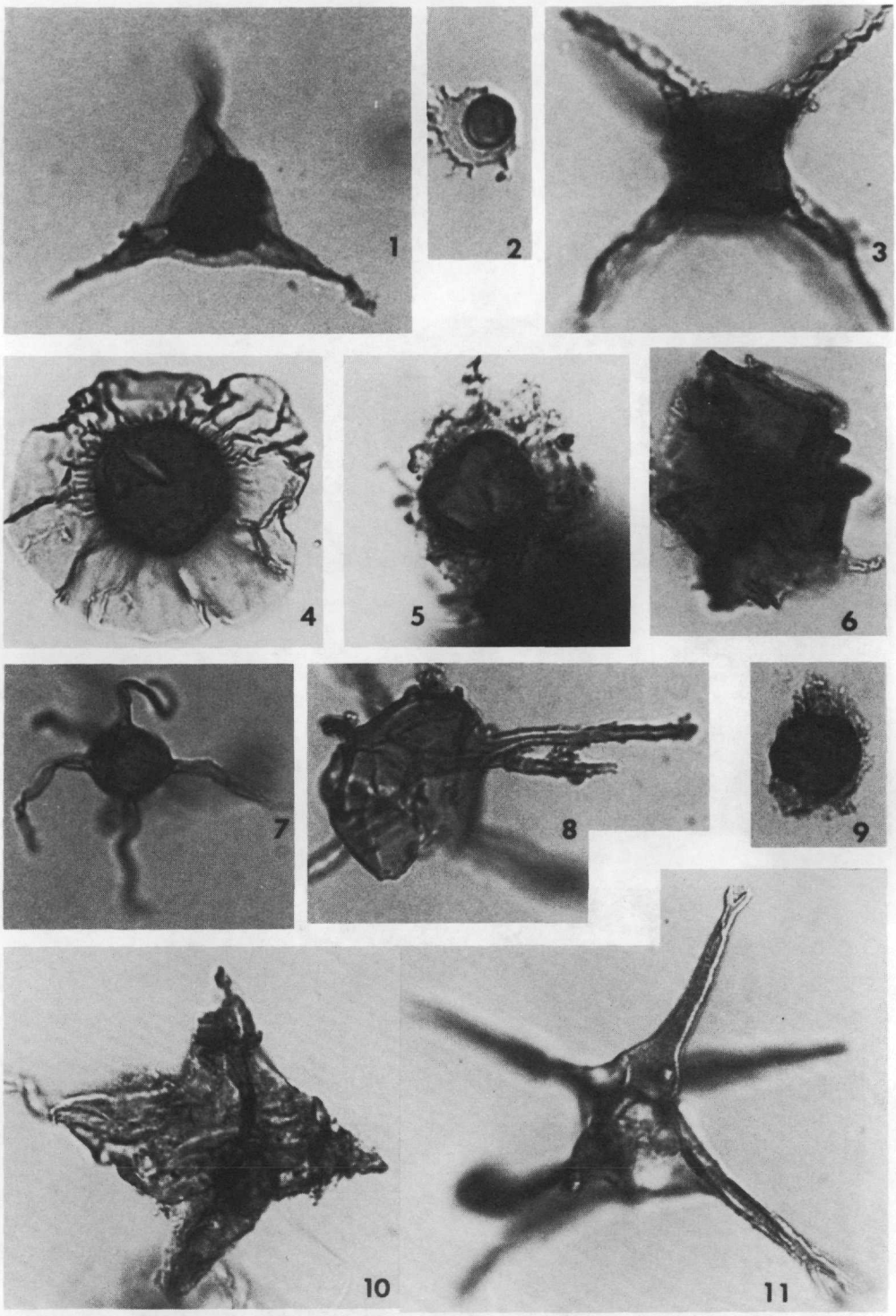

FIGURE 4

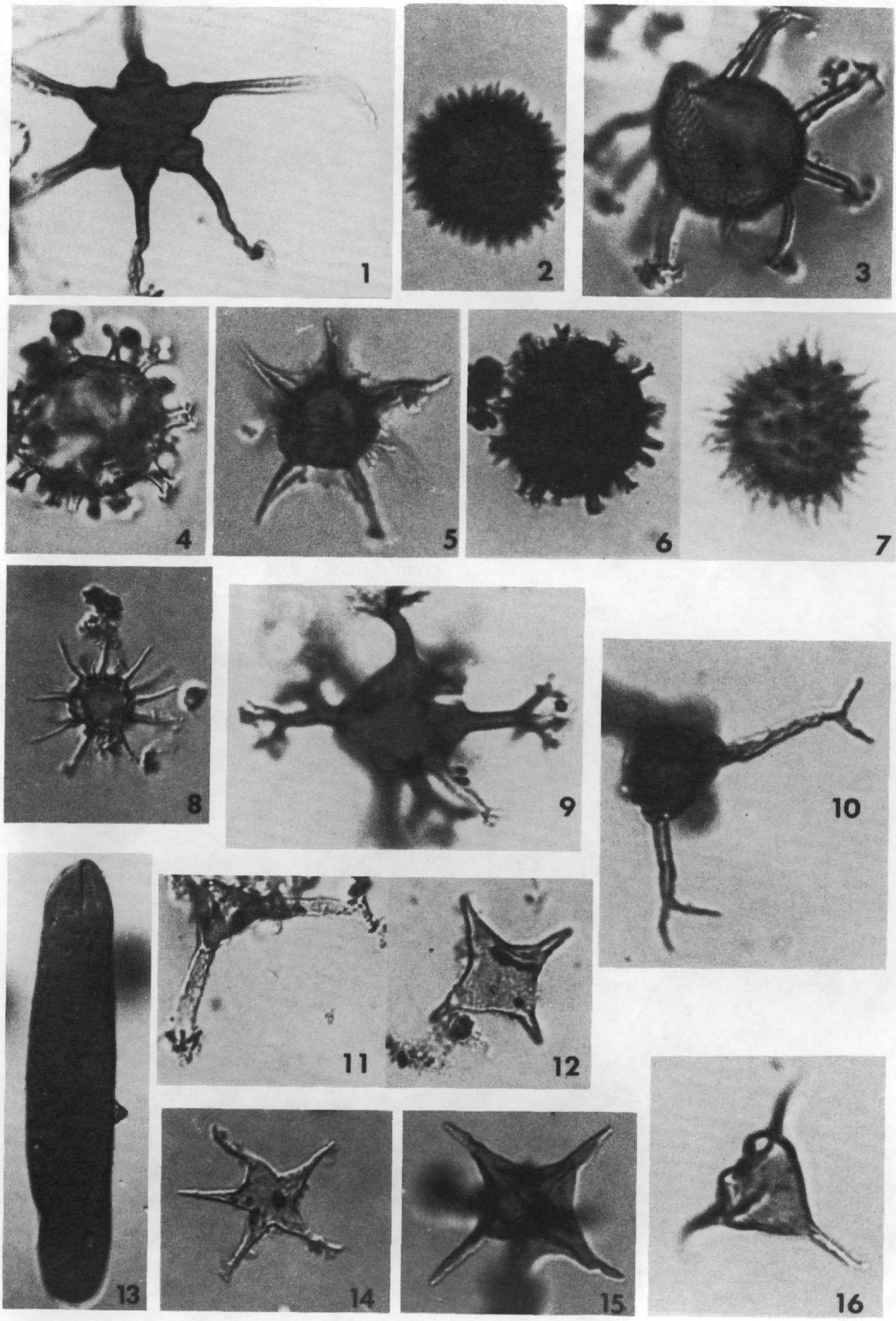

FIGURE 5

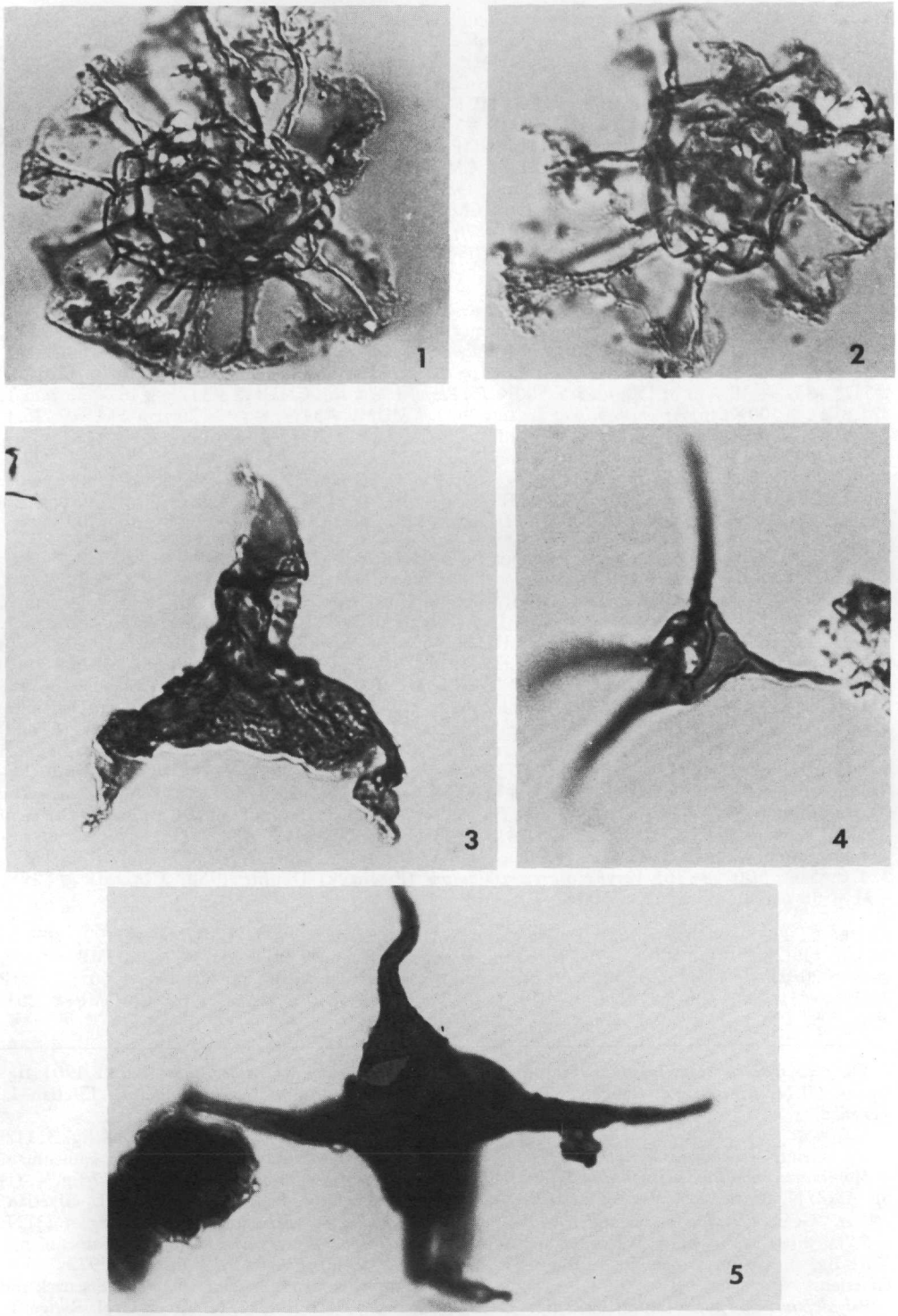

FIGURE 6

FIGURE 3. (1) *Cymatiosphaera canadensis* Deunff 1961. CMUMP #5160, #16 > 38 μm 3, 146.0; 14.0 500×. (2) *Cymatiosphaera cornifera* Deunff 1955. CMUMP #5161, #16 > 38 μm 3, 123.3; 3.7 500×. (3) *Cymatiosphaera* sp., CMUMP #5162, #41<38 μm 1, 132.3; 21.5. 500×. (4) *Dictyotidium cohora* Wicander and Wood 1981. CMUMP #5163, #41 > 38 μm 2, 129.6; 7.7. 500×. (5) *Dictyotidium* cf. *variatum* Playford 1977. CMUMP #5164, #22<38 μm 2, 123.5; 11.5. 500×. (6) *Duvernaysphaera angelae* Deunff 1964. CMUMP #5165, #31 > 38 μm 2, 122.7; 18.5. 500×. (7) *Duvernaysphaera tenuicingulata* Staplin 1961. CMUMP #5166, #31<38 μm 2, 126.6; 23.0. 500×. (8) *Muraticavea munificus* Wicander and Wood 1981. CMUMP #5167, #17 > 38 μm 1, 131.8; 17.5. 500×. (9) *Polyedryxium* cf.*ambitum* Wicander and Wood 1981. CMUMP #5168, #25 > 20 μm 3, 128.5; 16.7. 500×. (10) *Polyedryxium bathyaster* Deunff 1961. CMUMP #5169, #31 > 38 μm 3, 146.4; 13.3. 500×. (11) *Polyedryxium* cf. *diabolicum* Deunff 1961. CMUMP #5170, #16 > 38 μm 3, 132.5; 19.6. 500×. (12) *Polyedryxium embudum?* Cramer 1964. CMUMP #5171, #31 > 38 μm 3, 146.0; 21.3. 500×.

FIGURE 4. (1) *Polyedryxium fragosulum* Playford 1977. CMUMP #5172, #41 < 38 μm 2, 150.9; 5.4. 500×. (2) *Pterospermella* cf. *hermosita* (Cramer) Eisenack and Cramer 1973. CMUMP #5173, #17 > 30 μm 3, 126.0; 13.8. 500X. (3) *Polyedryxium pharaonis* Deunff 1961. CMUMP #5174, #31 > 38 μm 2, 126.8; 7.7. 500×. (4) *Pterospermella reticulata* Loeblich and Wicander 1976. CMUMP #5175, #31 > 38 μm 3, 150.4; 15.5. 500×. (5) *Pterospermella* sp., CMUMP #5176, #16 > 38 μm 1, 121.8; 17.6. 500×. (6) *Arkonites bilixus* Legault 1973. CMUMP #5177, #43 > 20 μm 1, 116.7; 16.1. 500×. (7) *Baltisphaeridium distentum* Playford 1977. CMUMP #5178, #16 > 38 μm 1, 142.8; 13.7. 500×. (8) *Diexallophasis simplex* Wicander and Wood 1981. CMUMP #5179, #30 > 20 μm 1, 112.7; 14.4. 500×. (9) *Dasypilula* sp., CMUMP #5180, #24 > 30 μm 1, 123.4; 8.9. 500×. (10) *Estiastra rhytidoa* Wicander and Wood 1981. CMUMP #5181, #43 > 20 μm 3, 137.4; 13.4. 500×. (11) *Exochoderma arca* Wicander and Wood 1981. CMUMP #5182, #31 > 38 μm 3, 120.9; 6.6. 500×.

FIGURE 5. (1) *Goniolopadium prolixum* Playford 1977. CMUMP #5183, #41 > 38 μm 3, 139.5; 18.6. 700X. (2) *Gorgonisphaeridium inflatum* Wicander and Wood 1981. CMUMP #5184, #16 < 39 μm 1, 143.9; 20.0. 500×. (3) *Hapsidopalla chela* Wicander and Wood 1981. CMUMP #5185, #13 > 38 μm 2, 136.0; 10.7. 500×. (4) *Hapsidopalla exornata* (Deunff) Playford 1977, CMUMP #5186, #13 > 38 μm 1, 143.2; 14.6. 500×. (5) *Induoglobus* sp., CMUMP #5187, #16 > 38 μm 3, 128.8; 11.4. 500×. (6) *"Micrhystridium paucispinum"* Deunff 1961. CMUMP #5188, #24 > 38 μm 3, 130.6; 14.5. 500×. (7) *Micrhystridium* sp. A., CMUMP #5189, #17 > 38 μm 3, 149.4; 17.3. 500×. (8) *Micrhystridium* sp. B., CMUMP #5190, #31 < 38 μm 2, 150.3; 8.2. 500×. (9) *Multiplicisphaeridium ramusculosum* (Deflandre) Lister 1970. CMUMP #5191, #31 > 38 μm 2, 121.2; 15.7. 500×. (10) *Ozotobrachion furcillatus* (Deunff) Playford 1977 CMUMP #5192, #17 > 38 μm 2, 150.0; 13.0. 500×. (11) *Ozotobrachion dactylos* Loeblich and Drugg 1968. CMUMP #5193, #13 < 38 μm 1, 142.4; 5.9. 500×. (12) *Veryhachium lairdi* (Deflandre) ex Deunff 1959. CMUMP #5194, #13 < 38 μm 1, 145.2; 21.0. 500×. (13) *Navifusa bacillum* (Deunff) Playford 1977. CMUMP #5195, #17 > 38 μm 2, 121.5; 15.6. 500×. (14) *Palacanthus ledanoisi* (Deunff) Playford 1977. CMUMP #5196, #13 < 38 μm 1, 129.0; 4.7. 500×. (15) *Stellinium octoaster* (Staplin) Jardiné, Combaz, Magloire, Peniguel, and Vachey, 1972. CMUMP #5197, #16 > 38 μm 3, 121.6; 5.4. 500×. (16) *Veryhachium trispinosum* (Eisenack) Deunff 1954. CMUMP #5198, #31 < 38 μm 1, 133.2; 12.4. 500×.

FIGURE 6. (1–2) *Tunisphaeridium tentaculaferum* (Martin) Cramer 1971. CMUMP #5199, #31 > 38 μm 1, 128.5; 4.3. 500×. (3) *Tyligmasoma alargadum* (Cramer) Playford 1977. CMUMP #5200, #43 > 20 μm 1, 146.2; 6.3. 500×. (4) *Veryhachium europaeum* Stockmans and Willière, 1960. CMUMP #5201, #31 > 38 μm 3, 123.2; 6.4. 400X. (5) *Veryhachium pastoris* Deunff 1966. CMUMP #5203, #16 > 38 μm 1, 135.3; 9.5. 500×.

Duvernaysphaera tenuicingulata Staplin 1961 fig. 3, (7) N. Amer. Geol. Range: L. Emsian–L. Frasnian.

Genus *Muraticavea* Wicander 1974

Muraticavea munificus Wicander and Wood 1981 fig. 3, (8) N. Amer. Geol. Range: E.–L. Givetian.

Genus *Polyedryxium* Deunff 1961

Polyedryxium cf. *ambitum* Wicander and Wood 1981 fig. 3, (9) N. Amer. Geol. Range: E.–L. Givetian.

Polyedryxium bathyaster Deunff 1961 fig. 3, (10) N. Amer. Geol. Range: L. Emsian–L. Givetian.

Polyedryxium cf. *diabolicum* Deunff 1961 fig. 3, (11) N. Amer. Geol. Range: E. Eifelian–L. Givetian.

Polyedryxium embudum? Cramer 1964 fig. 3, (12) N. Amer. Geol. Range: E. Emsian–L. Famennian.

Polyedryxium fragosulum Playford 1977 fig. 4, (1) N. Amer. Geol. Range: L. Siegenian–L. Givetian.

Polyedryxium pharaonis Deunff 1961 fig. 4, (3) N. Amer. Geol. Range: L. Siegenian–L. Famennian.

Genus *Pterospermella* Eisenack 1972

Pterospermella cf. *hermosita* (Cramer) Eisenack and Cramer 1973 fig. 4, (2) N. Amer. Geol. Range: L. Givetian.

Pterospermella reticulata Loeblich and Wicander 1976 fig. 4, (4) N. Amer. Geol. Range: L. Gedinnian–L. Givetian.

Pterospermella sp. fig. 4, (5) REMARKS: This species is similar to the *Pterospermella* sp. figured by Wicander and Wood (1981) from the Silica Formation.

Group Acritarcha Evitt 1963

Genus *Arkonites* Legault 1973

Arkonites bilixus Legault 1973 fig. 4, (6) N. Amer. Geol. Range: E.–L. Givetian.

Genus *Baltisphaeridium* Eisenack 1958

Baltisphaeridium distentum Playford 1977 fig. 4, (7) N. Amer. Geol. Range: L. Siegenian–L. Givetian.

Genus *Dasypilula* Loeblich and Wicander 1976

Dasypilula sp. fig. 4, (9) REMARKS: This species is similar to *Dasypilula* sp. figured by Wicander and Wood (1981) from the Silica Formation.

Genus *Diexallophasis* Loeblich 1970

Diexallophasis simplex Wicander and Wood 1981 fig. 4, (8) N. Amer. Geol. Range: E.–L. Givetian.

Genus *Estiastra* Eisenack 1959

Estiastra rhytidoa Wicander and Wood 1981 fig. 4, (10) N. Amer. Geol. Range: E.–L. Givetian.

Genus *Exochoderma* Wicander 1974

Exochoderma arca Wicander and Wood 1981 fig. 4, (11) N. Amer. Geol. Range: E.–L. Givetian.

Genus *Goniolopadium* Playford 1977

Goniolopadium prolixum Playford 1977 fig. 5, (1) N. Amer. Geol. Range: E.–M. Givetian.

Genus *Gorgonisphaeridium* Staplin, Jansonius and Pocock 1965

Gorgonisphaeridium inflatum Wicander and Wood 1981 fig. 5, (2) N. Amer. Geol. Range: E.–L. Givetian.

Genus *Hapsidopalla* Playford emend. Wicander and Wood 1981

Hapsidopalla chela Wicander and Wood 1981 fig. 5, (3) N. Amer. Geol. Range: E.–L. Givetian.

Hapsidopalla exornata (Deunff) Playford 1977 fig. 5, (4) N. Amer. Geol. Range: L. Eifelian–L. Famennian.

Genus *Induoglobus* Loeblich and Wicander 1976

Induoglobus sp. fig. 5, (5) DESCRIPTION: Vesicle circular in outline, 18 μm in diameter; wall laevigate; 7–8 processes, 16 μm long, bordered by a thin diaphanous list that extends to adjacent processes; processes appear to communicate with vesicle; no method of excystment observed. REMARKS: Only a few specimens of this distinctive species were found, and it was decided not to establish a new species based on the limited number found. The occurrence of this genus extends its geologic range from the Late Gedinnian to the Givetian.

Genus *Micrhystridium* Deflandre 1937

"Micrhystridium paucispinum" Deunff 1961 fig. 5, (6) N. Amer. Geol. Range: E. Eifelian–L. Givetian.

Micrhystridium sp. A fig. 5, (7) REMARKS: This is the same species reported by Wicander and Wood (1981) from the Silica Formation.

Micrhystridium sp. B fig. 5, (8) REMARKS: This is the same species reported by Wicander and Wood (1981) from the Silica Formation.

Genus *Multiplicisphaeridium* Staplin emend. Staplin, Jansonius and Pocock 1965

Multiplicisphaeridium ramusculosum (Deflandre) Lister 1970 fig. 5, (9) N. Amer. Geol. Range: L. Siegenian–L. Givetian.

Genus *Navifusa* Combaz, Lange and Pansart 1967

Navifusa bacillum (Deunff) Playford 1977 fig. 5, (13) N. Amer. Geol. Range: E. Emsian–L. Famennian.

Genus *Ozotobrachion* Loeblich and Drugg 1968

Ozotobrachion dactylos Loeblich and Drugg 1968 fig. 5, (11) N. Amer. Geol. Range: L. Gedinnian–M. Eifelian.

Ozotobrachion furcillatus (Deunff) Playford 1977 fig. 5, (10) N. Amer. Geol. Range: L. Gedinnian–L. Givetian.

Genus *Palacanthus* Wicander 1974

Palacanthus ledanoisi (Deunff) Playford 1977 fig. 5, (14) N. Amer. Geol. Range: E. Emsian–L. Givetian.

Genus *Stellinium* Jardiné, Combaz, Magloire, Peniguel and Vachey 1972

Stellinium octoaster (Staplin) Jardiné, Combaz, Magloire, Peniguel and Vachey 1972 fig. 5, (15) N. Amer. Geol. Range: E. Emsian–L. Famennian.

Genus *Tunisphaeridium* Deunff and Evitt 1968

Tunisphaeridium tentaculaferum (Martin) Cramer 1971 fig. 6, (1–2) N. Amer. Geol. Range: Silurian–L. Givetian.

Genus *Tyligmasoma* Playford 1977

Tyligmasoma alargadum (Cramer) Playford 1977 fig. 6, (3) N. Amer. Geol. Range: E. Emsian–L. Givetian.

Genus *Veryhachium* Deunff ex Downie 1959

Veryhachium europaeum Stockmans and Willière 1960 fig. 6, (4) N. Amer. Geol. Range: E.–L. Givetian.

Veryhachium lairdi (Deflandre) ex Deunff 1959 fig. 5, (12) N. Amer. Geol. Range: L. Siegenain–L. Givetian.

Veryhachium pastoris Deunff 1966b fig. 6, (5) N. Amer. Geol. Range: E.–L. Givetian.

Veryhachium trispinosum (Eisenack) Deunff 1954b fig. 5, (16) N. Amer. Geol. Range: Ordovician–Mississippian.

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LITERATURE CITED

Chapel, J. 1975 Petrology and depositional history of Devonian carbonates in Ohio. Unpubl.

Ph.D. Thesis, The Ohio State University, Columbus.

Combaz, A., F. W. Lange and J. Pansart 1967 Les "Leiofusidae" Eisenack, 1938. Rev. Palaeobot. Palynol. 1: 207–307.

Conkin, J. E. and B. M. Conkin 1975 Middle Devonian bone beds and the Columbus-Delaware (Onondagen-Hamiltonian) contact in central Ohio. Bull. Amer. Paleontol. 67: 99–122.

Cramer, F. H. 1964 Microplankton from three Paleozoic Formations in the province of León NW-Spain. Leidse Géol. Meded., 30: 253–361.

——— 1971 Distribution of selected Silurian acritarchs. Rev. Españ. Micropaleontol. Num. extraord.: 1–203.

Deflandre, G. 1937 Microfossiles des silex crétacés. Deuxième partie. Flagellés incertae sedis Hystrichosphaeridés Sarcodinés. Organismes Divers. Ann. Paléontol. 26: 51–103.

——— 1954 Systématique des Hystrichosphaeridés: sur l'acception de genre *Cymatiosphaera* O. Wetzel. C. R. Soc. geol., France 12: 257–258.

Deunff, J. 1954a Sur un microplancton du Dévonien du Canada recélant des types nouveaux d'Hystrichosphaeridés. C. R. Acad. Sci., Paris, France. 239: 1064–1066.

——— 1954b Microorganismes planctoniques (hystrichosphéres) dans le Dévonien du Massif armoricain. C. R. Soc. Geol., France, 11: 239–242.

——— 1955 Un microplancton fossile Dévonien à hystrichosphères du continent Nord-Américain. Bull. Microsc. Appl., Sér. 2, 5: 138–149.

——— 1957 Microorganismes nouveaux (hystrichosphères) du Dévonien de l'Amérique du Nord. Bull. Soc. Géol. Minéral., Bretagne, n.s., 12: 5–14.

——— 1959 Microorganismes planctoniques du Primaire amoricain I. Ordovicien du Veryhac'h (Presqu'ile de Crozon). Bull. Soc. Géol. Minéral., Bretagne n.s., 14: 1–41.

——— 1961 Quelques précisions concernant les hystrichosphaeridées du Dévonien du Canada. C. R. Soc. Géol. France 8: 216–218.

——— 1964 Le genre *Duvernaysphaera* Staplin. Grana Palynol. 5: 210–215.

——— 1966a Recherches sur les microplanctons du Dévonien (Acritarches et Dinophyceae). The Author, Thèse Univ. Renes: 1–168.

——— 1966b Acritarches du Dévonien du Tunisie. Soc. Géol. Fr., C. R. somm., 1: 22–24.

——— 1971 Le genre *Polyedryxium* Deunff—Révision et observations. *In:* Microfossiles organiques du Paléozoique, fasc. 3, Commission Internationale de Microflore du Paleozoique: 7–49.

——— and W. R. Evitt 1968 *Tunisphaeridium,* a new acritarch genus from the Silurian and Devonian. Stanford Univ. Publ., Geol. Sci., 12: 1–13.

Downie, C. 1959 Hystrichospheres from the Silurian Wenlock Shale of England. Palaeontol., 2: 56–71.

Droste, J. B., R. H. Shaver and J. D. Lazor 1975 Middle Devonian paleogeography of the Wabash Platform, Indiana, Illinois, and Ohio. Geology 3: 725–728.

Eisenack, A. 1958 Microplankton aus dem norddeutschen Apt nebst einigen Bemerkungen über fossile dinoflagellaten. N. Jb. Geol. Paläont. Abh., 106: 383–422.

——— 1959 Neotypen baltischer silurhystrichosphären und neue Arten. Palaeontographica, 112A: 193–211.

——— 1972 Kritische Bemerkung zur Gattung *Pterospermopsis* (Chlorophyta, Prasinophyceae). N. Jb. Geol. Paläont. Mh., 10: 596–601.

——— and F. H. Cramer 1973 Katalog der fossilen dinoflagellaten, Hystrichosphären und verwandten mikrofossilien, Bd. III. Acritarcha 1. Teil, Stuttgart, E. Schweizerbart sche Verlagsbuchhandlung: 1–1104.

Evitt, W. R. 1963 A discussion and proposals concerning fossil dinoflagellates, hystrichospheres and acritarchs, I, II. Natl. Acad. Sci. Proc., 49: 158–164, 298–302.

Jardiné, S., A. Combaz, L. Magloire, G. Peniguel and G. Vachey 1972 Acritarches du Silurien terminal et du Dévonien du Sahara Algérien. C. R. Septième Cong. Int. Stratigr. Géol. Carbonifere, Krefeld (Aug. 1971), 1: 295–311.

Legault, J. A. 1973 Chitinozoa and Acritarcha of the Hamilton Formation (Middle Devonian), southwestern Ontario. Geol. Surv. Canada., Bull. 121: 1–103.

Lister, T. R. 1970 A monograph of the acritarchs and chitinozoa from the Wenlock and Ludlow Series of the Ludlow and Millichope areas, Shropshire Part I. Paleontogr. Soc. Monogr., 124: 1–100.

Loeblich, A. R., Jr. 1970 Morphology, ultrastructure and distribution of Paleozoic acritarchs. North Amer. Paleontol. Conv., Chicago (1969), Proc. G: 705–788.

——— and W. S. Drugg 1968 New acritarchs from the Early Devonian (Late Gedinnian) Haragan Formation of Oklahoma, USA Tulane Stud. Geol., 6: 129–137.

——— and E. R. Wicander 1976 Organic-walled microplankton from the Lower Devonian Late Gedinnian Haragan and Bois d'Arc Formations of Oklahoma, USA. Part I. Paleontographica 159B: 1–39.

Playford, G. 1977 Lower to Middle Devonian acritarchs of the Moose River Basin, Ontario. Geol. Surv. Canada., Bull. 279: 1–87.

Staplin, F. L. 1961 A reef-controlled distribution of Devonian microplankton in Alberta. Palaeontol., 4: 392–424.

———, J. Jansonius and S. A. J. Pocock 1965 Evaluation of some acritarchous hystrichosphere genera. N. Jb. Geol. Palaontol., Abh., 123: 167–201.

Stauffer, C. R. 1909 The Middle Devonian of Ohio. Ohio Geol. Sur. Bull. 10: 1–204.

Stockmans, F. and Y. Willière 1960 Hystrichosphères du Dévonien belge (Sondage de l'Asile

d'aliénés á Tournai). Senck. Leth., 41: 1–11.
Wicander, E. R. 1974 Upper Devonian-Lower Mississippian acritarchs and prasinophycean algae from Ohio, U.S.A. Palaeontographica, 148B: 9–43.
——— (In press) Biostratigraphy and catalog of the North American Devonian organic-walled microphytoplankton. Amer. Assoc. Strat. Palyn. Contrib. Ser.
——— and G. D. Wood 1981 Systematics and biostratigraphy of the organic-walled microphytoplankton from the Middle Devonian (Givetian) Silica Formation, Ohio, USA. Amer. Assoc. Strat. Palyn. Contrib. Ser. No. 8: 1–137.
Wright, R. P. 1976 Occurrence, stratigraphic distribution, and abundance of chitinozoa from the Middle Devonian Columbus limestone of Ohio. Ohio J. Sci. 76: 214–224.
——— 1978 Biogeography of Middle Devonian chitinozoa of the midwestern United States. Palinologia, Numero extraordinario 1: 501–505.
——— 1980 Middle Devonian chitinozoa of Indiana. Indiana Geol. Surv. Special Rept. 18: 1–24.